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Review Article

Linking sufficiency and the protection of biodiversity: An issue of political implications, framing, descriptiveness and interdisciplinarity?

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Abstract

The dramatic loss of biodiversity is caused by the use of resources and land. One strategy aiming at reducing the use of resources and land is sufficiency, which consequently could be a strategy for protecting biodiversity. This article therefore examines the extent to which sufficiency in the context of biodiversity conservation is already being addressed by nature conservation associations and the scientific community. To this end, publications were analysed firstly with regards to the understanding of sufficiency, secondly with regards to the considered links between sufficiency and biodiversity as well as thirdly with regards to the considered fields of action. The systematic identification and evaluation of scientific publications (for the years 2017–2021) and publications by German and international nature conservation associations shows that few publications address the link between sufficiency and biodiversity. And when they do, the link often remains unspecific. Possible reasons are that sufficiency potentially has broader political implications, that the term is not descriptive and that other terms are used to describe similar strategies. Other potential explanations are that several framings for the need for sufficiency are possible and that linking sufficiency and biodiversity requires interdisciplinarity. Drawing on the results and the discussion, an argument in favour of using the term 'sufficiency' and further research is presented. Moreover, a sufficiency typology is developed and questions are raised that could form the basis for future research on linking biodiversity conservation and the various aspects of sufficiency.

Key words: Biodiversity conservation, biodiversity loss, sufficiency, sustainability strategies

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Introduction

The loss of biodiversity, as described in the Living Planet Report (WWF 2020) or the Global Assessment Report on Biodiversity and Ecosystem Services (IPBES 2020), is dramatic. Land-use change, direct exploitation, invasive species, climate change and pollution are named as the main drivers of biodiversity loss (see e.g. IPBES 2020, p. 245). These are caused by human activities such as agriculture, forestry, fishing, farming, mining and energy production, among others (IPBES 2020). This means that the loss of biodiversity is largely due to human use of resources and land which consequently needs to be reduced.

One strategy that aims at an absolute reduction of resource consumption is 'sufficiency'. As a term for a sustainability strategy, besides 'efficiency' and 'consistency' it was first used in the German-speaking world by Sachs (1993). He describes sufficiency as a "principle of self-restraint" (Sachs 2015, p. 4), which includes 'deceleration', 'regionality', 'common good economy', 'reinvention of the commons' and a modified or specific 'art of living'. Linz (2002) explains that in the "narrower understanding [sufficiency] forms the counterpart to efficiency, is directed towards the reduced consumption of resources and is thus quantitatively oriented. The broader understanding [of sufficiency] is directed towards a new sense of prosperity and towards cultural change, which is both its precondition and its result" (Linz 2002, p. 13, own translation). Fischer et al. (2013) describe sufficiency as "changes in consumption patterns that help to stay within the Earth's ecological carrying capacity, changing utility aspects of consumption" (Fischer et al. 2013, p. 13, own translation). Finally, the IPCC 2022 report defines sufficiency policy as "a set of measures and daily practices that avoid demand for energy, materials, land and water while delivering human wellbeing for all within planetary boundaries" (IPCC 2022, p. 31). Although there are a variety of definitions, the term sufficiency seems to stand for a strategy to reduce resource consumption, which can simultaneously include aspects of social change, social justice and the consideration of planetary boundaries.

The fact that, firstly, a reduction in resource consumption is imperative for the conservation of biodiversity and, secondly, sufficiency is a strategy that aims to reduce resource consumption suggests that sufficiency contributes to the conservation of biodiversity. This raises the question of the extent to which sufficiency as a strategy for the conservation of biodiversity is addressed by the scientific community, and in particular by the disciplines that deal with nature conservation, as well as by nature conservation associations. In order to investigate this systematically, scientific publications and publications by nature conservation associations were analysed under the following questions:

1. How is sufficiency understood or defined?
2. How are sufficiency and biodiversity linked?
3. Which sufficiency action field is the focus of the publication?

Following the answers to these questions, the results are discussed and a typology of sufficiency is proposed.

Methodology

To answer the research questions, a systematic literature review was conducted. The procedure is based on the content structuring analysis as described by Kuckartz (2018): Firstly, the publications to be examined are systematically identified and narrowed down, secondly, deductive-inductive categories are formed and a word environment analysis is carried out (cf. Fig. 1).

Identification of relevant publications

Both scientific publications and publications by nature conservation organisations were included in the analysis. The scientific literature was identified using the

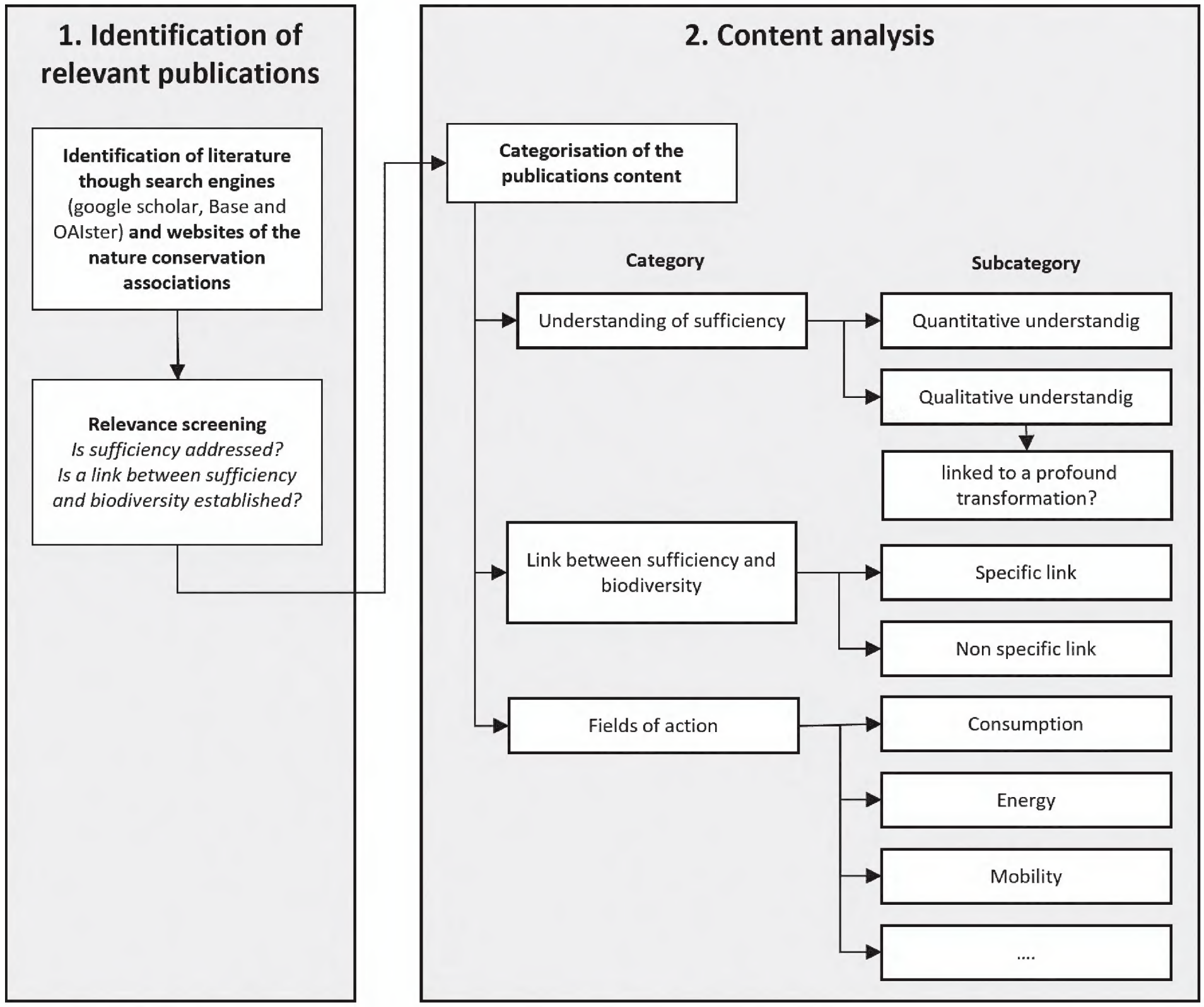

Figure 1. Methodology.

search engines BASE, OAIster and Google Scholar using the keywords 'sufficiency', 'biodiversity', 'nature conservation' and 'consumption' or 'production'. Only publications that were published between 2017 and 2021 as well as written in German or English were evaluated. This temporal restriction was made in order to determine the current state of discussion. In order to filter out non-relevant publications, the search settings were adjusted (where possible) so that publications with terms such as 'self-sufficiency', 'insufficient' and 'sufficiency of' were not displayed.

Nature conservation associations were analysed both at the national level in Germany and internationally. To determine the publications of German nature conservation associations and foundations, the websites of German nature conservation organisations with a strong presence in the public debate and high membership numbers were analysed. These are: Naturschutzbund Deutschland (NABU), Greenpeace Deutschland, World Wide Fund for Nature Deutschland (WWF Deutschland) and Bund für Umwelt und Naturschutz Deutschland (BUND). This search was carried out via the websites of these organisations at federal and federal state level. In the search for publications of international nature conservation organisations and networks, the main pages of Greenpeace, WWF, International Union for Conservation of Nature (IUCN) and Friends of the Earth were searched. These organisations or networks were selected partly because of their

size and partly because they are the 'umbrella organisations' of the German organisations surveyed. The IUCN is an exception to this but was selected additionally as assessing and protecting Biodiversity is a focal point of the organisation.

The keywords used in the search for publications of the nature conservation associations were 'Suffizienz' (German) and 'Sufficiency' (English) and 'Biodiversität' (German) and 'Biodiversity' (English). A restriction to a specific time period, as in the search for scientific publications, was not possible in the search on the websites of the nature conservation associations and was therefore not carried out. The evaluation was also not limited to specific years, as the year of publication was not specified in some cases.

The publications identified in this way were subjected to a relevance screening based on their tables of contents and summaries as well as a keyword ('sufficiency' as well as 'biodiversity') search. For the further evaluation, only publications were considered that firstly dealt with sufficiency as a sustainability strategy in the sense described above and secondly established a link between biodiversity and sufficiency.

Content analysis

For conducting the content analysis categories were defined. These were derived from the research questions mentioned above. The sub-categories were then developed deductively-inductively.

Category 'Understanding of sufficiency'

As mentioned above, sufficiency can be defined and understood in different ways. Therefore, it is also necessary to consider the respective understanding of sufficiency. Due to the large number of different definitions and following Linz (2002), a first step is to distinguish between a qualitative and a quantitative understanding of sufficiency.

A quantitative understanding of sufficiency refers to views in which sufficiency is aimed exclusively at the mere reduction of resource consumption. The qualitative understanding of sufficiency encompasses this quantitative aspect, but goes beyond it by also including socio-cultural change. This may involve a redefinition of prosperity, among other things.

In the next step, the qualitative understanding of sufficiency was further differentiated and it was examined whether the authors of the publications see sufficiency as being linked to a profound transformation of economic conditions and society. A critical attitude towards economic growth and capitalism, statements on the necessity of 'degrowth' and 'post-growth', as well as remarks on far-reaching changes in power structures and the distribution of property were evaluated as indications for such an understanding.

Category 'Link between sufficiency and biodiversity'

In this category, a distinction was made between specific and non-specific connections.

The subcategory 'unspecific connection' includes publications that mention biodiversity loss as a reason for the need for sufficiency or imply that sufficiency

is necessary for the protection of biodiversity, without explaining this further. Publications that describe how sufficiency contributes to the conservation of biodiversity in greater detail are assigned to the category 'specific context'.

Category 'Fields of action'

The publications were – if possible - assigned to a field of action based on the system of Demuth and Heiland (2020). Fields of action are understood here as economic and socially significant areas that are distinguished from one another by functions or tasks. The fields of action were then supplemented by the inductive formation of subcategories.

The fields of action considered are: Consumption, energy, mobility, housing, work, agriculture and food, forestry, mining, travel and tourism, research and teaching, regional development and spatial planning, and nature conservation.

With regard to the field of action 'nature conservation', it should be noted that, since only publications that establish a connection between biodiversity and sufficiency were evaluated, the publications ultimately deal with the field of action 'nature conservation', since biodiversity conservation is a central aspect of nature conservation. However, the field of action 'nature conservation' as defined here encompasses the explicit engagement with social issues of nature conservation, nature conservation policy demands or nature conservation narratives.

The evaluation of the texts in relation to fields of action was carried out through the qualitative evaluation of the text sections dealing with sufficiency. In the case of the scientific texts, the one field of action that was considered was assigned. If several fields of action were considered as examples, no allocation was made. Several fields of action were not assigned to one publication, as the scientific publications did not take an in-depth look at several fields of action. It should, however, be noted that there are overlaps between the fields of action. For the purpose of classifying the content of the publications, and because almost all fields have points of contact with each other, a corresponding differentiation of the fields while at the same time making the classification unambiguous seems heuristically sensible.

The publications of the nature conservation associations were treated differently from the scientific publications with regard to the allocation of fields of action, as these publications often considered fields of action such as mining in relation to nature conservation. In the case of the evaluation of the publications of the nature conservation associations, the assignment to a further field of action was therefore made in addition to the assignment to the field of action nature conservation, provided that this second field of action was a central object of consideration of the publication.

Content analysis procedure

The paragraphs in which the terms biodiversity or sufficiency appeared were systematically analysed and the content was classified according to the categories described above.

In addition to the methodology described above, the translation assistance of DeepL, an AI assistant tool, was used in the preparation of the manuscript.

Results

The search for scientific publications yielded a total of 494 hits for the years from 2015 to 2021. These were narrowed down to 44 publications after the screening described above (see Suppl. material 1), which is strikingly low. In 20 of these publications, sufficiency and biodiversity or one of the two terms was mentioned only in passing, i.e., only once and/or without explaining it in more detail. Eleven publications are in English, whereby these are predominantly written by German authors, and 33 are in German. Furthermore, the type of documents differs: There are four articles in journals (three of which have gone through a review process), two anthologies with several contributions on the topic, seven contributions in anthologies, five dissertations, four master's theses, three bachelor's theses, six monographs and thirteen publications that fall into the category of 'grey literature' (research reports, conference/event documentation, etc.).

The search for publications by nature conservation associations yielded 286 hits. The screening reduced the material classified as relevant to twelve publications (see Suppl. material 1). This was due to duplications in the respective hit lists and the use of the term sufficiency in the sense of 'sufficient'. The material classified as relevant includes both web pages and pdf documents. These are published exclusively by NABU, BUND and WWF (Germany) and are written in German.

In the following, the results are presented first for the scientific publications and then for the publications and websites of the nature conservation organisations.

Understanding of sufficiency

Scientific publications

Sufficiency is understood quantitatively in eleven of the 44 publications according to the definition presented above, and qualitatively in 24 cases. In nine other publications the understanding remains unclear. Here, the term is mentioned without further explanation. Of the 24 scientific texts with a qualitative understanding of sufficiency, 13 mention biodiversity loss/biodiversity only once or twice and 19 only make a general connection between biodiversity/biodiversity loss and sufficiency.

Eleven publications mention that there is a conflict between sufficiency and economic growth (Keck et al. 2017; Pufé 2017; Schiemann and Wilmsen 2017; Sperfeld et al. 2017; Witt 2017; Zahrnt, 2017; Miehe 2018; Biermann and Erne 2020; Dallmer 2020; Berger et al. 2021; Wyborn et al. 2021), so it can be concluded that for them sufficiency is linked to a profound transformation.

Publications by nature conservation associations

In the twelve publications of nature conservation associations examined, sufficiency is understood quantitatively in five cases and qualitatively in four cases. Three publications cannot be clearly assigned.

The extent to which a profound transformation is seen as a prerequisite for sufficiency is not noted in the NABU publications. A BUND publication (2022c) states: "Policies that are primarily oriented towards the goal of economic

growth are in stark contradiction to sustainable development and the world's limited resources" (BUND 2022c, own translation). The WWF publications do not address more fundamental changes in political and economic structures. One exception to this is WWF Germany's publication by Kind and Engel (2018) which states: "Alternative economic concepts to growth-oriented capitalism include the zero-growth, growth-reduction and sufficiency concepts" (Kind and Engel 2018, p. 76, own translation).

Link between sufficiency and biodiversity

Scientific publications

When looking at the links between sufficiency and biodiversity established in the scientific publications, it is striking that the necessity of sufficiency for the preservation of biodiversity is mentioned non-specifically in 32 of 44 publications.

The authors of twelve publications make specific links between the need for sufficiency in the face of biodiversity loss and the positive effects of sufficiency for biodiversity conservation: five publications describe the threat to biodiversity posed by agricultural practices and diets and consider sufficiency as a strategy for reducing this threat (Fehrenbach et al. 2017; Antos 2018; Fabricius 2018; Mok-Wendt 2020; Cohors-Fresenborg et al. 2021; Schlatzer et al. 2021). Three publications (Fehrenbach et al. 2017; Fabricius, 2018; Schlatzer et al. 2021) address the pressure on land use and sufficiency as a strategy to reduce this pressure. Other publications mention the positive and negative impacts on biodiversity that can result from sufficiency in tourism and recreational use (Schrader 2017; Zahrnt 2017; Antos 2018). Concrete positive correlations between sufficiency and biodiversity are shown in two publications for the forestry sector (Lippe et al. 2017; Creutzburg et al. 2020).

Publications by nature conservation associations

In contrast to the scientific publications, the publications of the nature conservation organisations more often consider the cause(s) of biodiversity loss and sufficiency as a way to combat those causes in more detail. For instance, they outline the negative impacts of chemicals (BUND 2022b), resource use in a bioeconomy (NABU 2022) and mining on biodiversity (BUND 2017; Kind and Engel 2018).

NABU publications also problematise the impacts of the energy transition on biodiversity: They highlight that the energy transition must be linked to energy sufficiency (Sothmann 2014; NABU Schleswig-Holstein 2019).

Fields of action

Fig. 2 shows the number of publications broken down by field of action. It should be noted that 17 scientific texts and two publications by nature conservation associations could not be assigned to a specific field of action. In these publications, fields of action are mentioned in passing. Haase (2020), for example, explains sufficiency in terms of mobility, Holzbaur (2020) in terms of agriculture and nutrition. The publications of the nature conservation associations

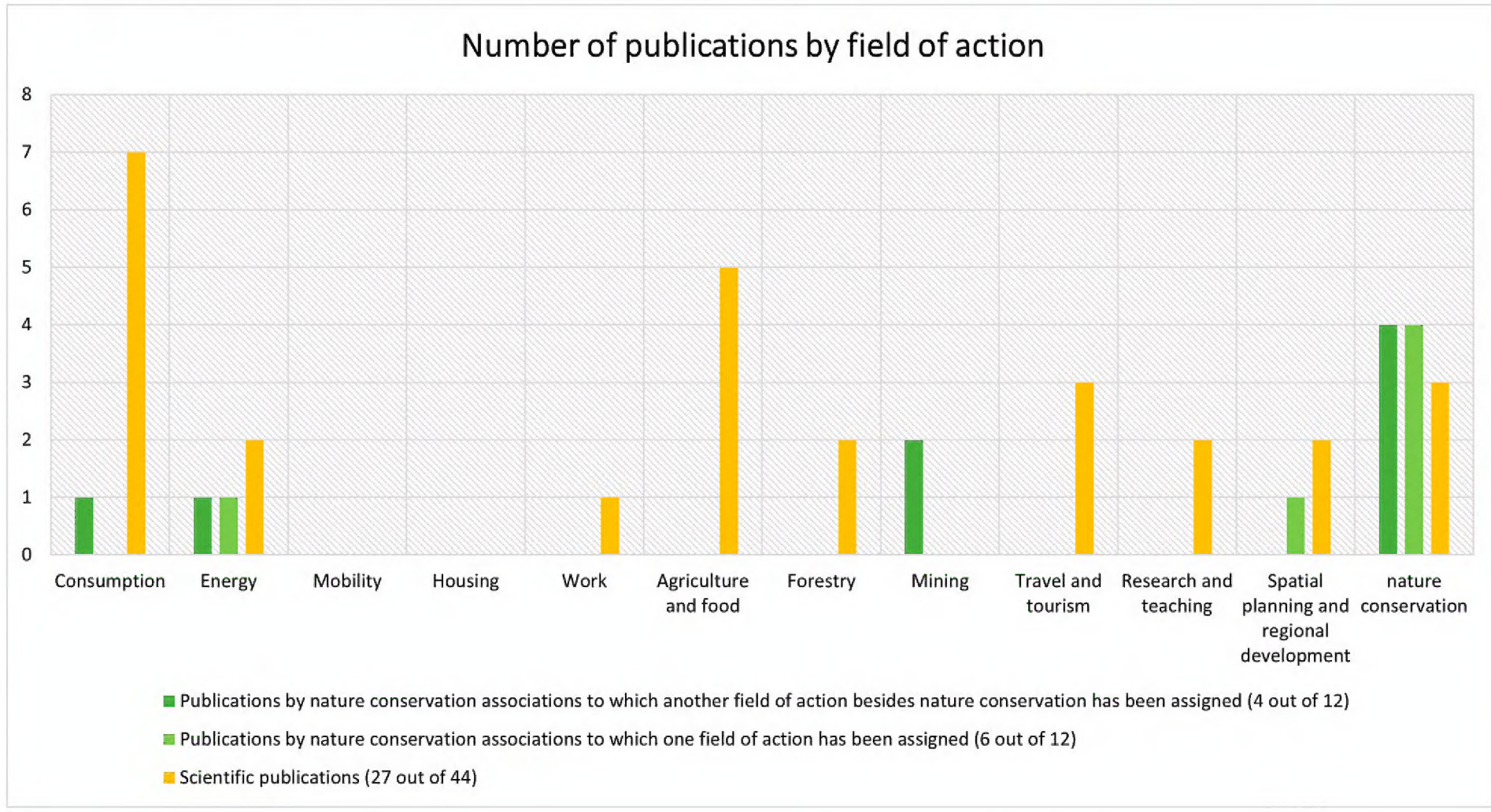

Figure 2. Fields of action.

that are not assigned to any field are a statement by BUND (2022a), and a text on the economy of transformation by the WWF (Zwiers et al. 2022).

The figure illustrates that in the publications of the associations in which sufficiency and biodiversity are linked the field of action 'nature conservation' is most frequently considered. In the scientific publications, the focus is most frequently on 'consumption' and 'agriculture and food'.

Statements and demands on the subject of sufficiency in publications on the field of action 'nature conservation'

A central aspect of this work is the consideration of the integration of sufficiency into biodiversity protection. As this is an essential task of nature conservation actors, central statements and demands on sufficiency from scientific publications on the field of action 'nature conservation' are presented below. Since biodiversity protection is also dependent on the spatial management of various anthropogenic land uses, the contents of publications on spatial planning are also listed.

- For effective environmental protection (as well as fair prices and wages), the "Western consumption model of constant increase cannot be continued" (Zahrnt 2017, p. 43, own translation). Thus, Sufficiency is necessary (see also Immovilli and Kok 2020, p. 21).
- Nature conservation (and conservationists) would have to discuss and reflect on its embedding in the imperial mode of living, "[f]or a sustainable social and economic system will not be achieved with efficiency and consistency strategies alone [...]. Sufficiency strategies are needed that pursue the goal of lower energy and material requirements and raise awareness of the non-material - i.e., emotional and social - dimensions of a 'good life'" (Leibenath et al. 2021, p. 147, own translation).

- Sufficiency will increase the importance of nature and thus increase the pressure on nature through uses such as domestic tourism and sport. Hence it is suggested to develop sufficiency strategies in the context of nature conservation as well as compensation measures for non-use (Zahrnt 2017, p. 43).
- For the implementation of sufficiency strategies, spatial planning and development, especially with regard to land-intensive economic and settlement developments, will play a decisive role (Hofmeister et al. 2021, p. 8).
- Sufficiency could reduce contradictions between climate protection and nature conservation caused by the energy transition (Sperfeld et al. 2017, p. 8).

Eight out of twelve texts from nature conservation associations focus on the field of action 'nature conservation'. Concrete statements or demands of the associations that link biodiversity conservation and sufficiency can be summarised under the following keywords:

- Nature-friendly energy transition by saving energy (Sothmann 2014; NABU 2021).
- Absolute resource reduction targets (WWF Deutschland 2020; BUND 2022c).
- Putting a stop to deep-sea mining (BUND 2017).

The other demands or statements of the conservation associations such as "a stronger focus should be placed on social and ecological innovations (sufficiency) for a truly sustainable economy" (NABU 2022, own translation) are less concrete.

Nevertheless, these publications contain proposals such as "no-go areas" for the protection of biodiversity (Kind and Engel 2018, p. 67), which are, however, not linked to sufficiency by the authors.

Discussion

The discussion focuses on the one hand on possible reasons for the small number of publications dealing with the link between biodiversity and sufficiency and the fact that the description of the link, when addressed, often remains unspecific, and on the other hand on the critical reflection on categorisation for the understanding of sufficiency.

Number of publications and specificity of the links

The result show, that the overall number of publications linking biodiversity with sufficiency is low. This also becomes evident when comparing the sustainability strategies sufficiency and efficiency with regard to biodiversity: a search with Google Scholar and the keywords 'sufficiency' and 'biodiversity' yielded 1.410 hits, whereas a search with the keywords 'efficiency' and 'biodiversity' yielded 9.320 hits (as of September 14th 2023). What could be the causes of these discrepancies?

Political implications

One reason could be controversies about the political implications of sufficiency as suggested by the following statement by a BUND expert: "[S]uf-

ficiency is […] questioning […] the current economic system and the growth paradigm. And that goes against the fundamental core logic of this society, this economy, this policy" (quoted in Huber 2023, p. 37). In other words, the term 'efficiency' is met with greater acceptance because it does not imply a restructuring of the existing economic and social conditions - and is therefore preferred. In contrast, the use of the term 'sufficiency' may imply this transformation. Spengler (2018) argues similarly: "In [...] several literature sources, there is talk of sufficiency 'policies', which are not policy instruments in the strict sense, but refer to broader socio-economic developments that would require a fundamental change in values and entire programmes of far-reaching political reforms. Examples are the "exit from growth policies", the "reduction of working hours [...] and the reduction of social inequality in order to reduce luxury and 'conspicuous' consumption" [...], which could indeed have significant effects in terms of mainstreaming sufficiency" (Spengler 2018 p. 37).

Descriptiveness

The lack of clarity of the term sufficiency could be another reason why it is used much less frequently. Linz (2004) for example, writes: "To the uninitiated, [the term sufficiency] says nothing or something wrong" (Linz 2004 p. 47, own translation). For Linz (2004), the meaning of sufficiency is therefore unclear for people who are not familiar with the term, or a completely different meaning is attributed to it. Making the term effective in the public sphere is consequently unpromising in his eyes (Linz 2004, p. 47,).

In this context, however, it is noteworthy that the French government adopted a 'plan de sobriété énergétique' (energy sufficiency plan) in autumn 2022 (Gouvernement français 2022). Sufficiency is presented as one of three pillars of the decarbonisation strategy. Energy sufficiency is thus very much present in the French public. Hence, the mainstreaming of the term sufficiency, at least in the area of energy sufficiency, should be possible (cf. also Ore 2022). However, in this plan sufficiency is hardly associated with the need for a 'deeper transformation' or 'growth critique' by the government. Rather, the use of the term seems to focus primarily on a purely quantitative reduction in energy consumption. Moreover, France seems to be the only country in Europe with a focus on energy sufficiency (Messad 2023). Nevertheless, sufficiency policies are recently taken up more prominently in Germany as well, as publications such as those by Reese et al. (2023) on sufficiency and environmental law or by Nawothnig et al. (2023) on sufficiency as a 'booster' for reaching climate protection targets show.

Different terminology

Another possible explanation for the low number of publications dealing with sufficiency and its links to biodiversity is that scientists and/or conservation organisations write about the related issues without using the term 'sufficiency', either paraphrasing similar strategies and analyses, or using other terms. Examples of paraphrases without the use of other terms can be found, in Moranta et al. (2022) and Otero et al. (2020).

Moranta et al. (2022) write that economic growth, which is linked to human activity and resource use, is the main cause of biodiversity loss. In order to counteract this, a fundamental change in social values and a downsizing of the economy are required. Otero et al. (2020) make a similar argument. They point out, again without explicitly using the term sufficiency, that "economic growth contributes to biodiversity loss via greater resource consumption and higher emissions" (Otero et al. 2020 2). Therefore, they suggest that the conflict between economic growth and biodiversity conservation needs to be acknowledged in policies (Otero et al. 2020, 2). Thus, both Moranta et al. (2022) and Otero et al. (2020) put forward arguments that - given the diversity of the sufficiency definition - could also be put forward for sufficiency.

One example of a strategy with similarities to sufficiency is degrowth. Hickel characterises degrowth as "a planned, coherent policy to reduce ecological impact, reduce inequality, and improve well-being [by, inter alia, scaling] down ecologically destructive and socially less necessary production (i.e. the production of SUVs, arms, beef, private transportation, advertising and planned obsolescence), while expanding socially important sectors like healthcare, education, care and conviviality" (Hickel 2021, p. 1108). Another concept with similarities to sufficiency is the concept of consumption corridors. In accordance to Fuchs et al. (2021) consumption corridors "describe a space between minimum consumption standards that provide every individual with the ability to live a good life, and maximum consumption standards that keep individuals from consuming in quantities or ways that hurt others' chances to do the same" (Fuchs et al. 2021 p. 4). It can be concluded from this that strategies with characteristics that could be attributed to sufficiency are discussed in the research without the term 'sufficiency' itself being mentioned. However, it is questionable whether the authors are familiar with the concept of sufficiency and whether or not they intentionally use other terms.

Framing and difficulties in in quantifying biodiversity loss

Another reason why only a small number of authors of scientific publications have used the term sufficiency to date could be that a discursive link between sufficiency and biodiversity has rarely been established. An expert from BUND Youth provides a possible explanation as to why this is the case: "This also raises the question of framing. So, on the one hand, what are the central problems we are actually referring to? Are we doing this for reasons of global justice, climate justice, biodiversity loss? All of those can be named. What does one refer to? And also: does one use the term sufficiency or not?" (cited in Huber 2023, p. 56). Thus, in addition to raising questions on terminology discussed above, this BUND Youth expert raises the question on how to frame sufficiency, suggesting that a variety of framings are possible. From this argumentation - and in view of the few publications that establish the connection between sufficiency and biodiversity - it can be concluded that the necessity of sufficiency is justified differently, i.e. other links are made between sufficiency and, for example, climate change. Is that the case? And if so, why?

When doing a Google search with the keywords 'sufficiency' and 'climate change' as well as 'sufficiency' and 'biodiversity loss' the number of hits for 'sufficiency' and 'climate change' is almost eleven times as high as the number for

sufficiency' and 'biodiversity loss' (972.000 hits and 88.700 hits, as of December 18th 2023). The conclusion that the need for sufficiency is more frequently justified by climate change than by the loss of biodiversity thus appears to be substantiated, although it should be noted that the content of the hits just mentioned was not analysed.

One possible explanation for the difference in the number of hits is that it is easier to assess the benefits of sufficiency as a strategy for mitigating climate change by calculating the savings in greenhouse gas emissions or energy consumption (see for example Burke 2020; Cordroch et al. 2022). However, even with rather practical approaches to measure biodiversity loss caused by land use, like proposed by Durán et al. (2020), quantifying impacts on biodiversity is more complex. The complexity and the associated difficulty in quantifying the loss of biodiversity could therefore be another reason for the small number of publications that establish a link between biodiversity and sufficiency. Furthermore, this could also be a reason why, even when a link between biodiversity and sufficiency is established, it often remains unspecific.

Another explanation indicated by the keyword search mentioned above as well as by looking at the Google hits for the keywords 'biodiversity crisis' compared to the keywords 'climate crisis' (74.200.000 hits and 864.000.000 hits, as of February 21st 2024), is that the climate change crisis appears to be more anchored in the public consciousness than the biodiversity crisis, despite both crises being related and should therefore be considered together (Pörtner et al. 2021).

Need for interdisciplinarity

Another reason for general statements on the link between biodiversity and sufficiency may be that biodiversity as a topic is primarily researched by natural scientists, especially biologists. Sufficiency, on the other hand, is a strategy aimed at changing individual lifestyles and social lifestyles, i.e., it deals with social behaviour. Sufficiency is therefore first and foremost an object of study for sociology. The link between sufficiency and biodiversity therefore requires an interdisciplinary perspective.

However, various factors make an interdisciplinary perspective difficult. According to Russels (2022) and MacLeod (2018), these factors include:

- different methodological approaches and technical terminology
- difficulties in reading and receiving texts from outside the discipline
- different conceptions of what the object of study is (or should be)

Moreover, according to Russels (2022), experts tend to focus on what they know.

An additional explanation for general statements about the link between biodiversity and sufficiency that affect both disciplinary and interdisciplinary research is provided by Leipold et al. (2024): They argue that underlying values and disciplinary paradigms influence collective science, constraining it and thus limiting its potential to contribute to inform and shape societal changes. They therefore propose a reflection on values and paradigms through a 'narrative led dialogue' (Leipold et al. 2024).

Understanding of sufficiency – and the need for a comprehensive typology

The results of this study show that the term sufficiency is defined, interpreted and understood in different ways. In order to be able to systematically identify and discuss the similarities and differences of sufficiency, a typology of sufficiency is essential.

A comparison of the typology proposed here with that of Lage (2022), which was published after the content evaluation for this paper, shows that a differentiation of the 'quantitative understanding of sufficiency' would also have been interesting for the analysis of the publications.

According to Lage (2022), a distinction should be made between 'sufficiency as consumption corridors' and 'sufficiency as a pathway towards a post-growth economy'. According to this differentiation, a distinction is made between, firstly, "[s]ufficiency [...] concepts in the sense of having the minimum necessary to live well and as limits to social practices that cause ecological damage, especially to consumption" (Lage, 2022 p. 5) and, secondly, concepts that, in addition to limiting consumption through corridors, strive for the development of an "a-growth or degrowth society or a steady-state economy, where societal prosperity is independent of economic growth" (Lage 2022, p. 6).

Comparing those sufficiency goals with the categories that were used here it becomes clear that the aspect of having 'enough', aimed at with the goal of 'sufficiency as consumption corridors' has not sufficiently been considered. A modified typology would therefore be useful for future studies of sufficiency. Accordingly, a distinction would have to be made as to whether sufficiency includes the following aspects:

1. reduction of resource consumption and environmental damage
2. changes in lifestyles and the meaning of wealth (e.g., the 'decluttering' or 'deceleration' mentioned by Sachs (1993))
3. social justice (especially with regard to the right of all people to a materially secure life)
4. explicit critique of growth or aspirations for an economy that is not dependent on economic growth

According to this typology, an understanding of sufficiency that only includes the first aspect would correspond to the 'quantitative understanding of sufficiency' examined here, whereas all understandings of sufficiency that include another aspect in addition to aspect 1 would correspond to the 'qualitative understanding of sufficiency'.

Conclusion

The systematic identification and evaluation of scientific publications (for the years 2017–2021) and publications by various nature conservation associations show that very few publications to date have addressed the link between sufficiency and biodiversity. And when they do, this linkage often remains unspecific and thus superficial.

Possible reasons for why very few publications deal with sufficiency are its political implications, the lack of descriptiveness of the term as well as the use of other terms. Moreover, the lack of, or unspecific linkages between sufficiency and biodiversity could be due to the fact that, firstly, several framings of the need for sufficiency are possible and, secondly, that sufficiency and biodiversity belong to different 'scientific spheres'. Linking the two terms thus requires a reflective, interdisciplinary perspective.

In the author's opinion, however, it nonetheless makes sense to further explore the potentials of sufficiency. Reasons are:

1. The biodiversity crisis is primarily caused by land use changes and direct exploitation. It therefore is caused by the mode of living and can consequently be mitigated through a change of that mode of living and the associated consumption of resources. Hence through a strategy such as sufficiency.
2. Sufficiency, depending on how it is understood, also raises questions of justice and the meaning of prosperity, and thus enables a joint consideration of social and biodiversity conservation concerns. This joint consideration is necessary for a just transformation towards sustainability.
3. For the reasons already mentioned, an interdisciplinary, if not transdisciplinary, perspective is in any case necessary in order to preserve biodiversity.
4. The fact that different framings for the necessity of sufficiency are possible, for example for the mitigation of climate change, does not make it less, but more sensible to take sufficiency into account.
5. Moreover, the example of the French 'plan de sobriété énergétique' shows that a mainstreaming of the term is possible.

Accordingly, and in view of the small number of publications that deal with the topic, sufficiency in the context of biodiversity protection should be researched in greater depth in the future. Starting points for further research could be the presented results under 3.3. as well as the typology and research questions presented in the following table (Table 1):

Table 1. Research questions on the link between sufficiency and biodiversity.

	Sufficiency typology (as developed under 4.2)	Research questions
1	Reduction of resource consumption (incl. land use) and environmental damage.	To what extent, where and how must resource use (including land use and intensity of use) be reduced to avert (further) negative effects on biodiversity?
2	Changing lifestyles and the meaning of wealth (e.g., the ‚decluttering' or ‚deceleration' mentioned by Sachs (1993)),	How does a change in lifestyles affect biodiversity (e.g. increased pressure on nature) and how can precautions be taken against potential negative impacts?
3	Social justice (especially with regard to the right of all people to a materially secure life)	How can both social impacts and impacts on biodiversity be taken into account in the consumption/use of resources (incl. land)? How must social impacts be taken into account when reducing resource use (with the aim of protecting biodiversity and considering that an increase in resource use, e.g., in the global south might also be necessary)?
		Which groups of people are affected by the reduction of resource use? Are they already marginalised in material terms, in terms of access to resources (e.g. green spaces, water, etc.)?
4	Explicit critique of an economic growth paradigm or aspirations for an economy not dependent on economic growth	Where are conflicts between economic interests on the one hand and biodiversity protection on the other? Or: Where do economic interests prevent biodiversity protection?

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Additional information

Conflict of interest

The author has declared that no competing interests exist.

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No ethical statement was reported.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Analysed publications

Authors: Marianne Hachtmann

Data type: xlsx

Explanation note: This appendix contains information on the publications analysed as part of the literature review. It therefore contains both baseline information and information about the content. Baseline information includes information on the authors, the year of publication, the title, the document type and the search engine used to find the publication. The information on the content is organised according to the categories described in the Methodology section (see also Fig. 1). Thus it contains information on the link between sufficiency and biodiversity, the understanding of sufficiency and the field of action the publication focuses on.

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